LHC beam screens: cryogenic observations in instrumented cells

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TE-CRG

E-cloud meeting
25th August 2017

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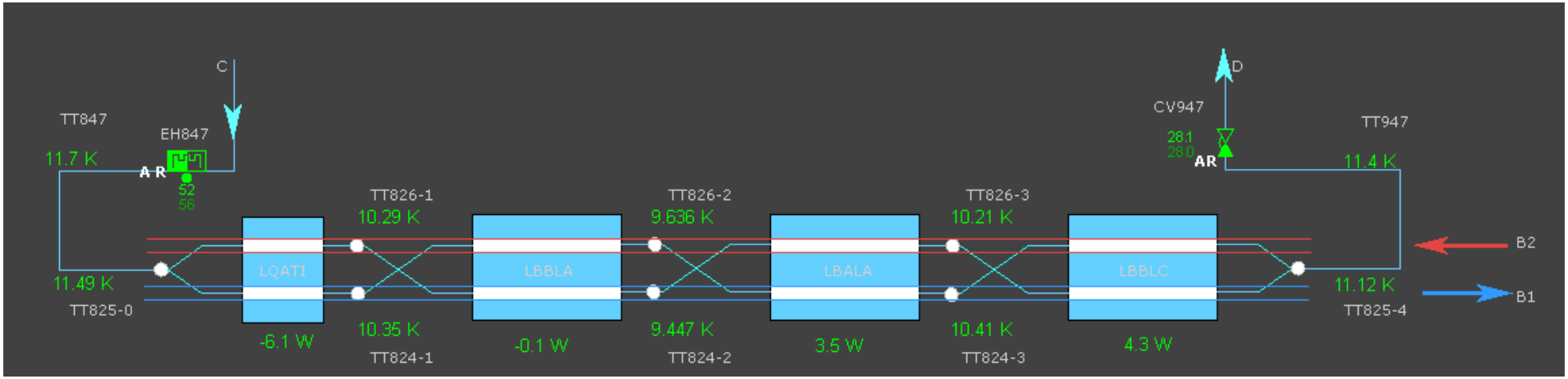
Nomenclature

Magnet number: Quad towards dipoles

Q1 D2 D3 D4



T0 Inlet temperatures

T1 (B1/B2)

T2 (B1/B2)

T3 (B1/B2)

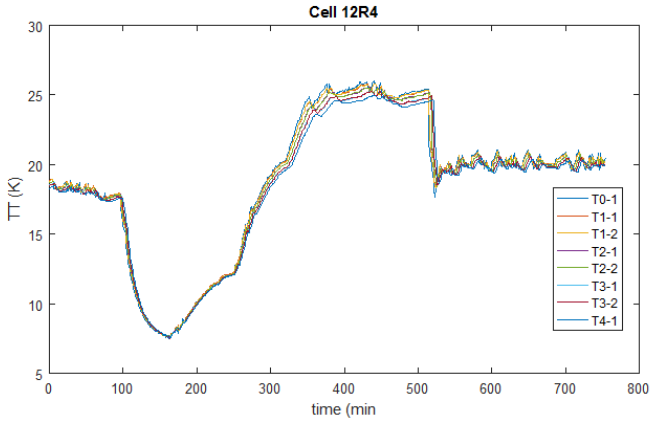
T4 Outlet temperatures

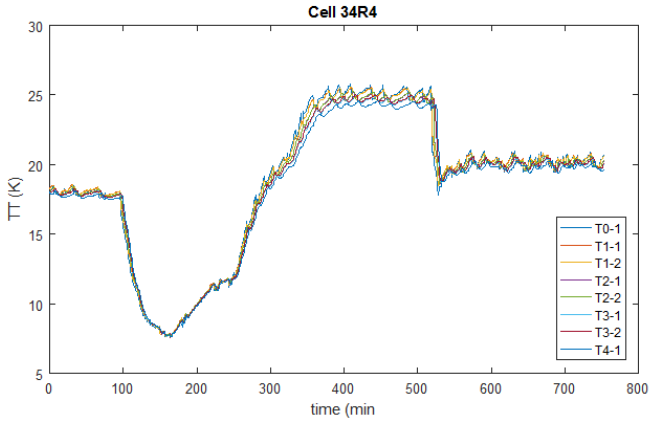
Sensor number: Helium Flow direction

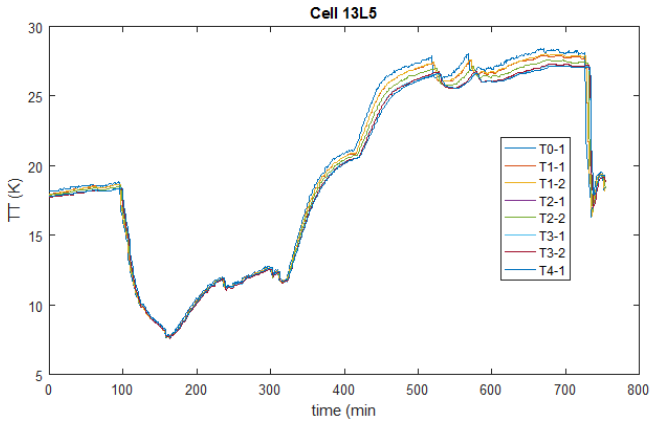
Sensor validation

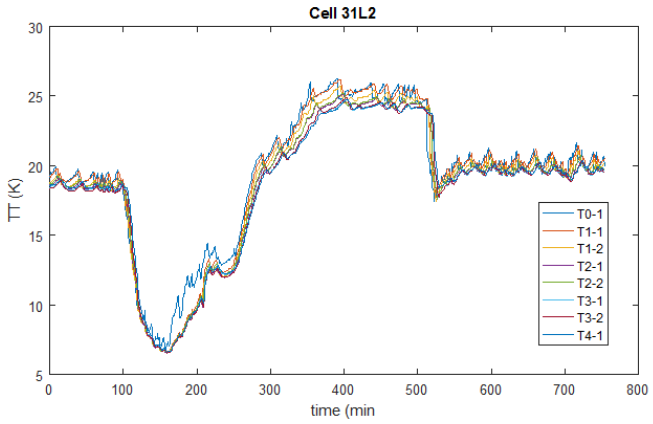
- Test without beam using electrical heater on 23rd July 2017
  - Change beam screen set-point along all the temperature range
  - Wait steady-state condition
  - Compute sensor standard deviations between each sensor located at same position

- Results : Standard Deviation < 0.1 K in the range [6 K ; 25 K]
  - QBS error < 0.5 W absolute ➔ QBS error normalized < 0.003 W/m/1e14 p+ (< 2% error)









Methodology

- Take 3 fills in June/July 2017
  - Fill #5821: Scrubbing 25 ns @ 450 GeV
  - Fill #5882: Physics 25 ns @ 6.5 TeV
  - Fill #5980: Physics 50 ns @ 6.5 TeV

- Compute the heat load per magnet and per aperture whenever it is possible

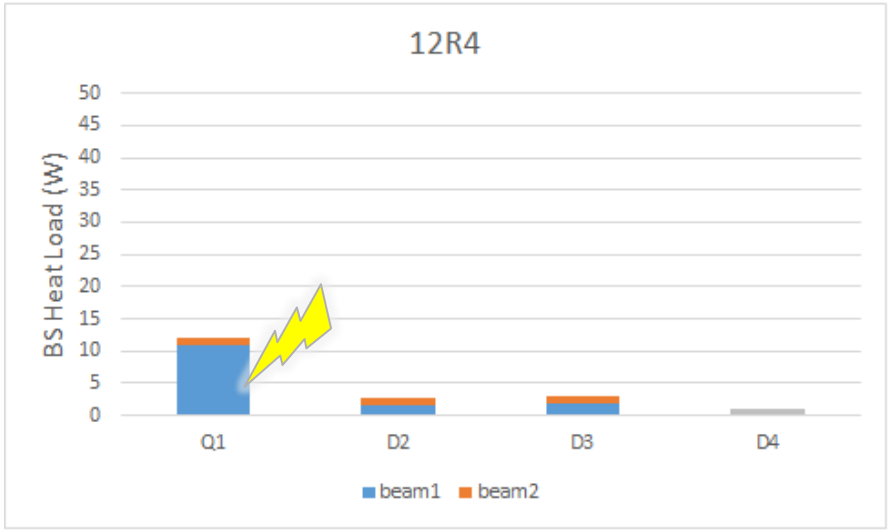
- Normalize the heat load per length and per total beam intensity

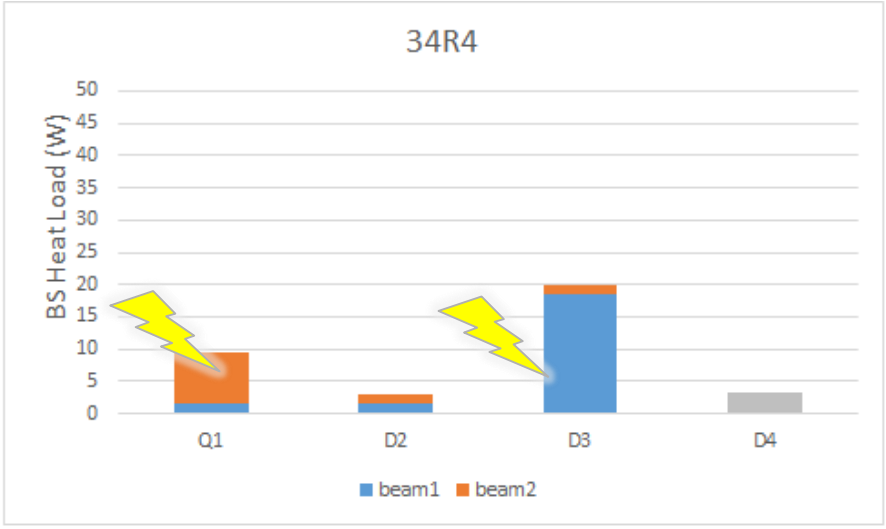
- Possible calculations
  - **Cells 13R4 and 34R4**
    - ✓ Each beam contribution for Q1,D2,D3 can be calculated
    - ✓ D4 magnet is calculated with 2 beams together (common sensor)
  - **Cell 13L5**
    - ✓ Each beam contribution for D4 can be calculated
    - ✓ D2 beam 1 cannot be calculated (one dead sensor)
    - ✓ D3 beam 2 cannot be calculated (one dead sensor)
    - ✓ Q1 magnet is calculated with 2 beams together (common sensor)
  - **Cell 31L2**
    - ✓ Each beam contribution for D2,D3,D4 can be calculated
    - ✓ Q1 magnet is calculated with 2 beams together (common sensor)

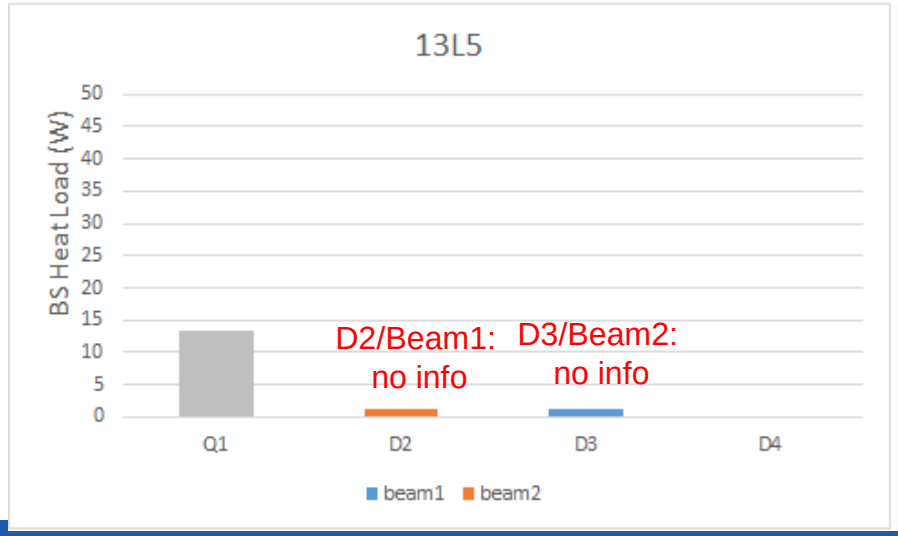
QBS at a glance (25ns @ 450 GeV)

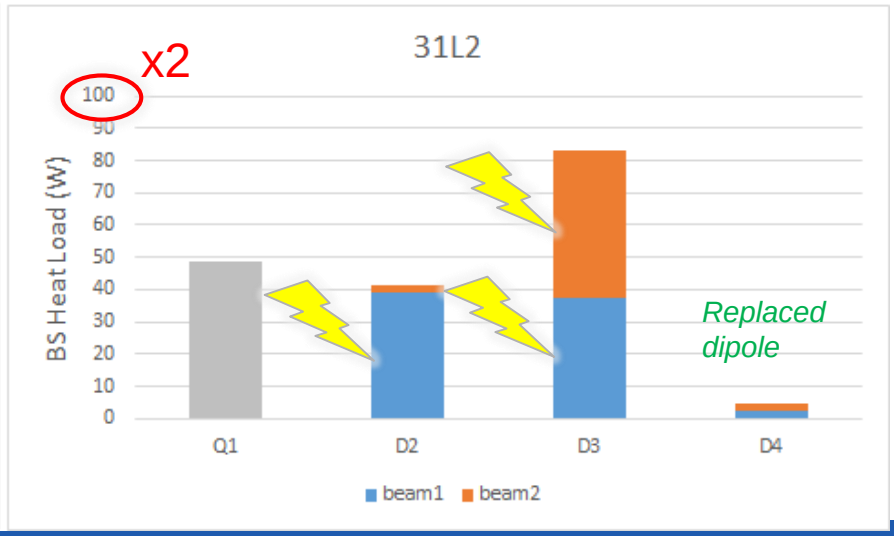
Fill #5821 @ 450 GeV (12th June 2017)
25ns_2820b_288bpi_scrub2017

- ➔ Large dispersion of heat loads across magnets
- ➔ Some asymmetries Beam1 / Beam 2





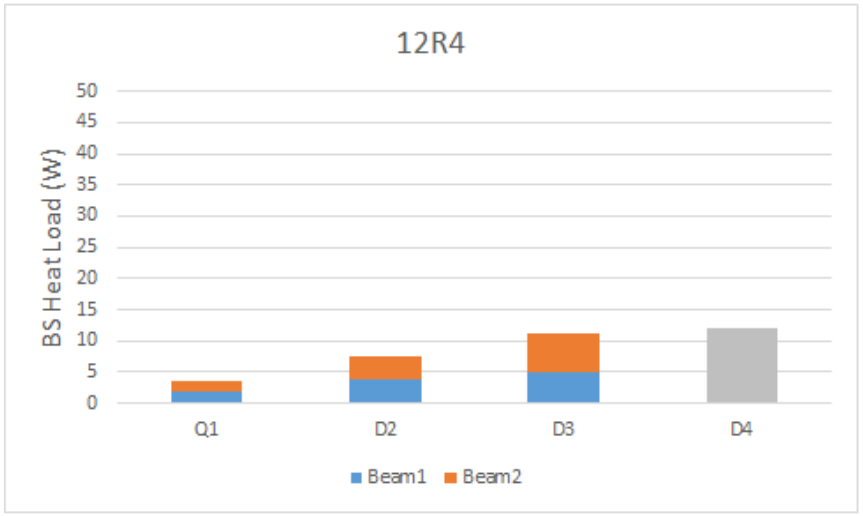


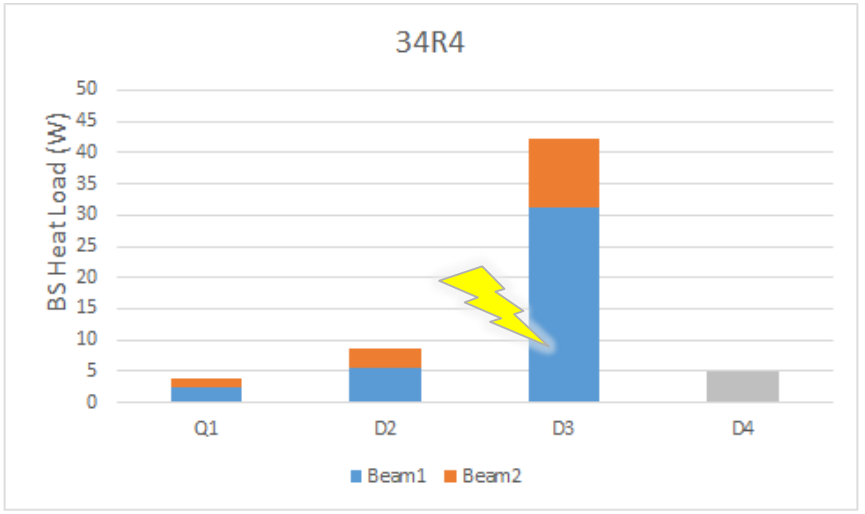


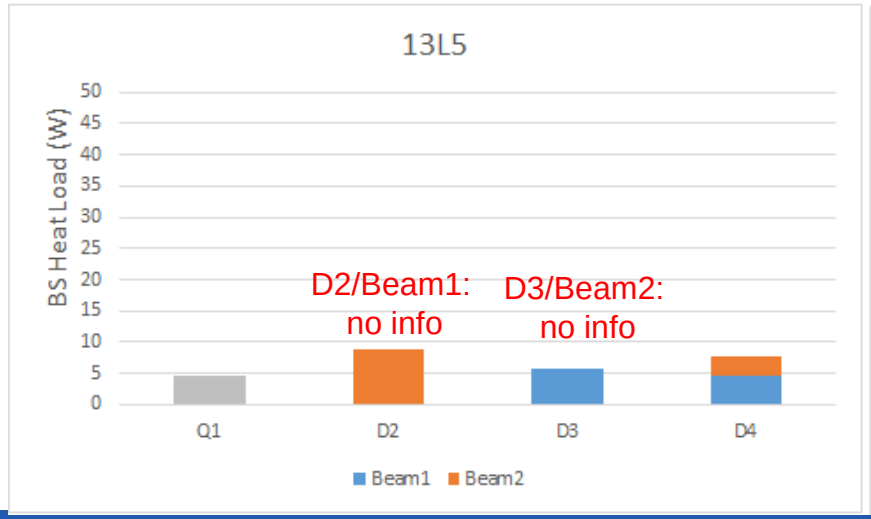
QBS at a glance (25ns @ 6.5 TeV)

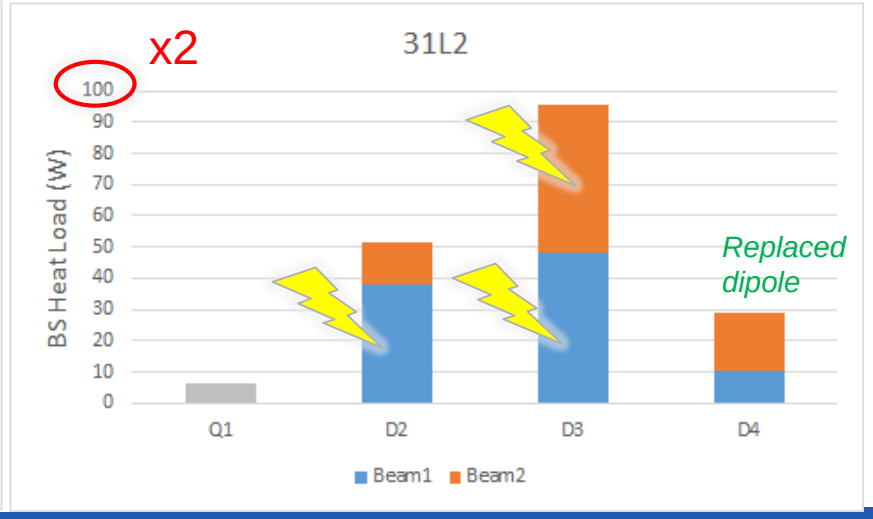
Fill #5882 @ 6.5 TeV (28th June 2017)
25ns_2556b_2544_2215_2332_144bpi_20inj

- ➔ Large dispersion of heat loads across magnets
- ➔ Some asymmetries Beam1 / Beam 2





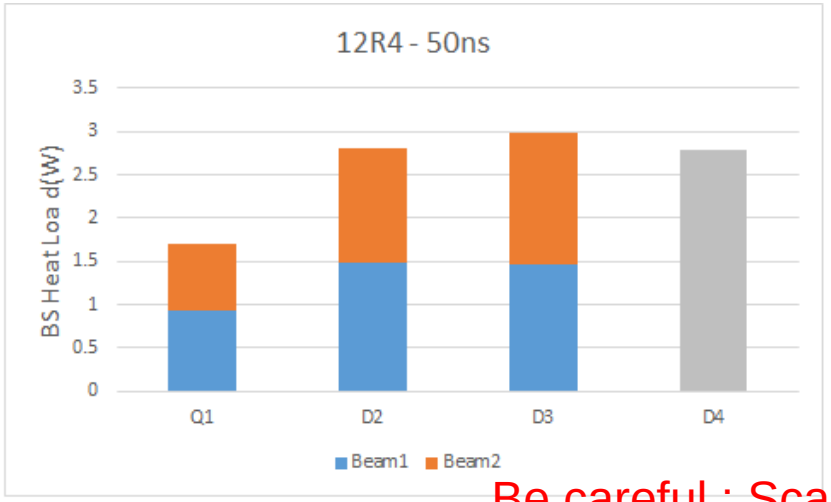


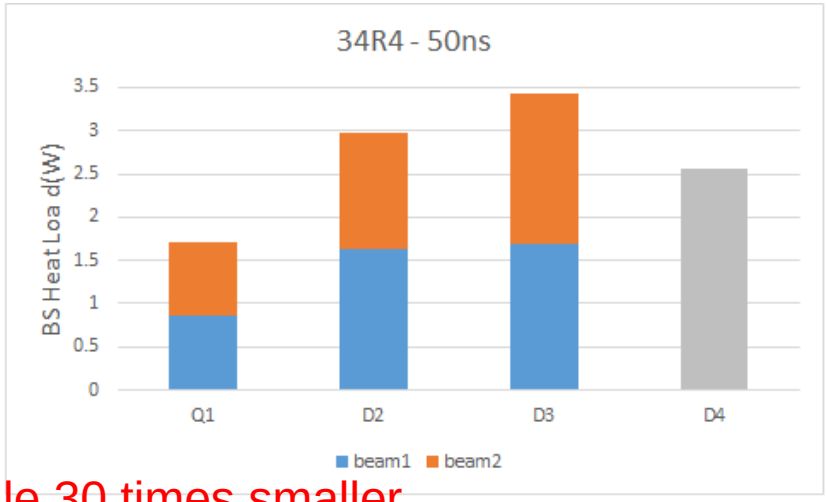


QBS at a glance (50 ns @ 6.5 TeV)

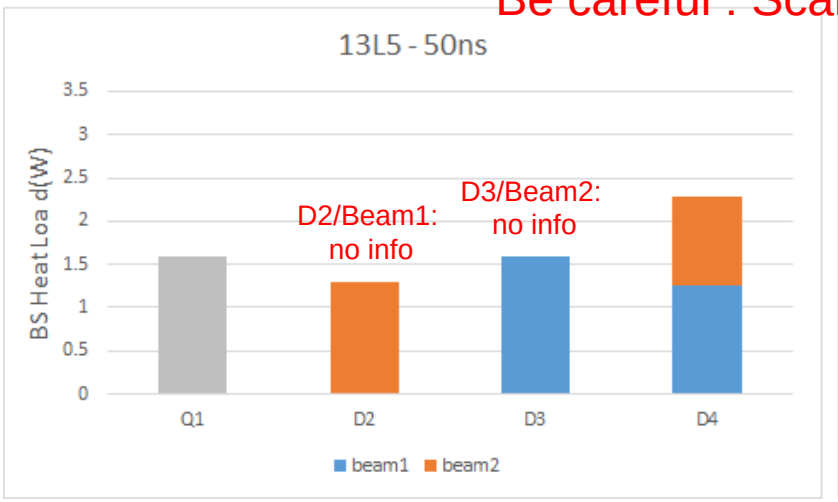
Fill #5980 @ 6.5 TeV (22nd July 2017)
50ns_1284b_1272_527_652_72bpi_20inj

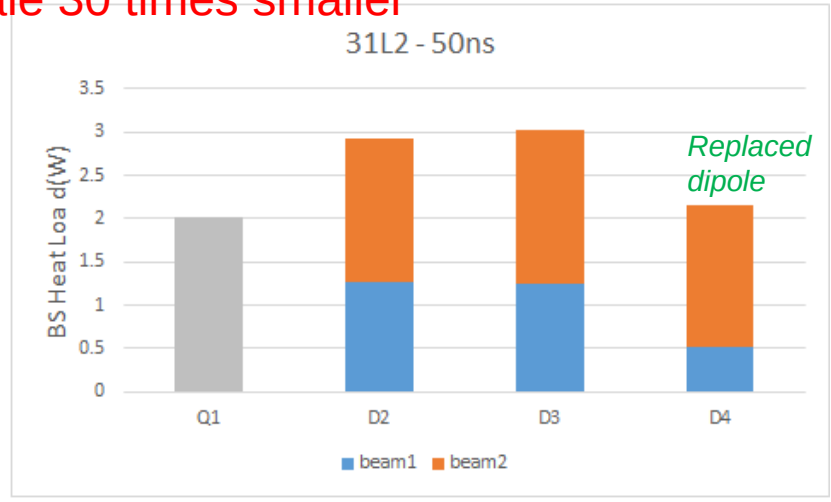
- ➔ Similar heat loads in all magnets
- ➔ No asymmetry Beam1 / Beam 2





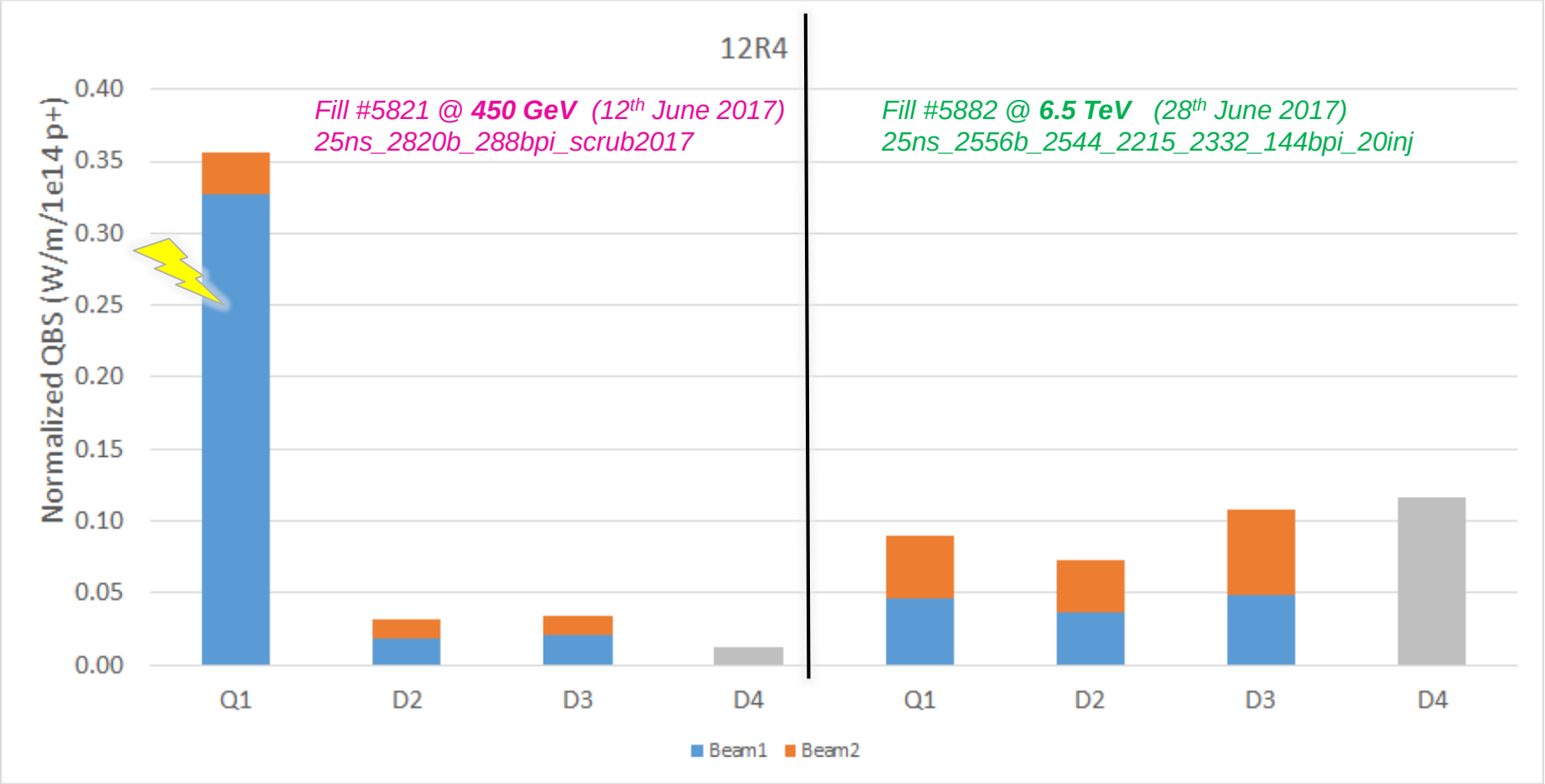
Be careful : Scale 30 times smaller





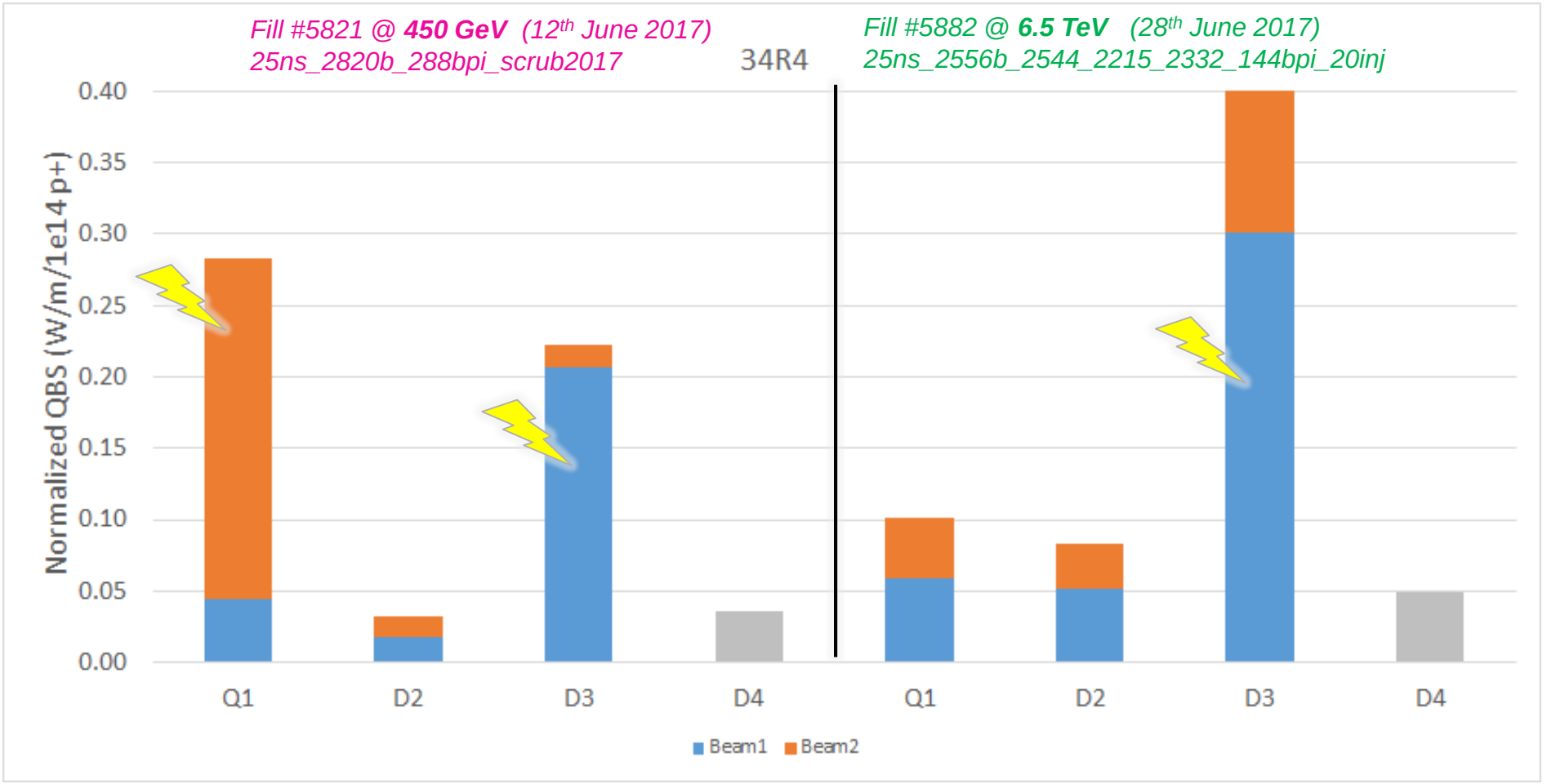
Normalized heat load in 12R4 @ 25 ns

1 anomaly:
- Q1 beam1 @ 450 GeV



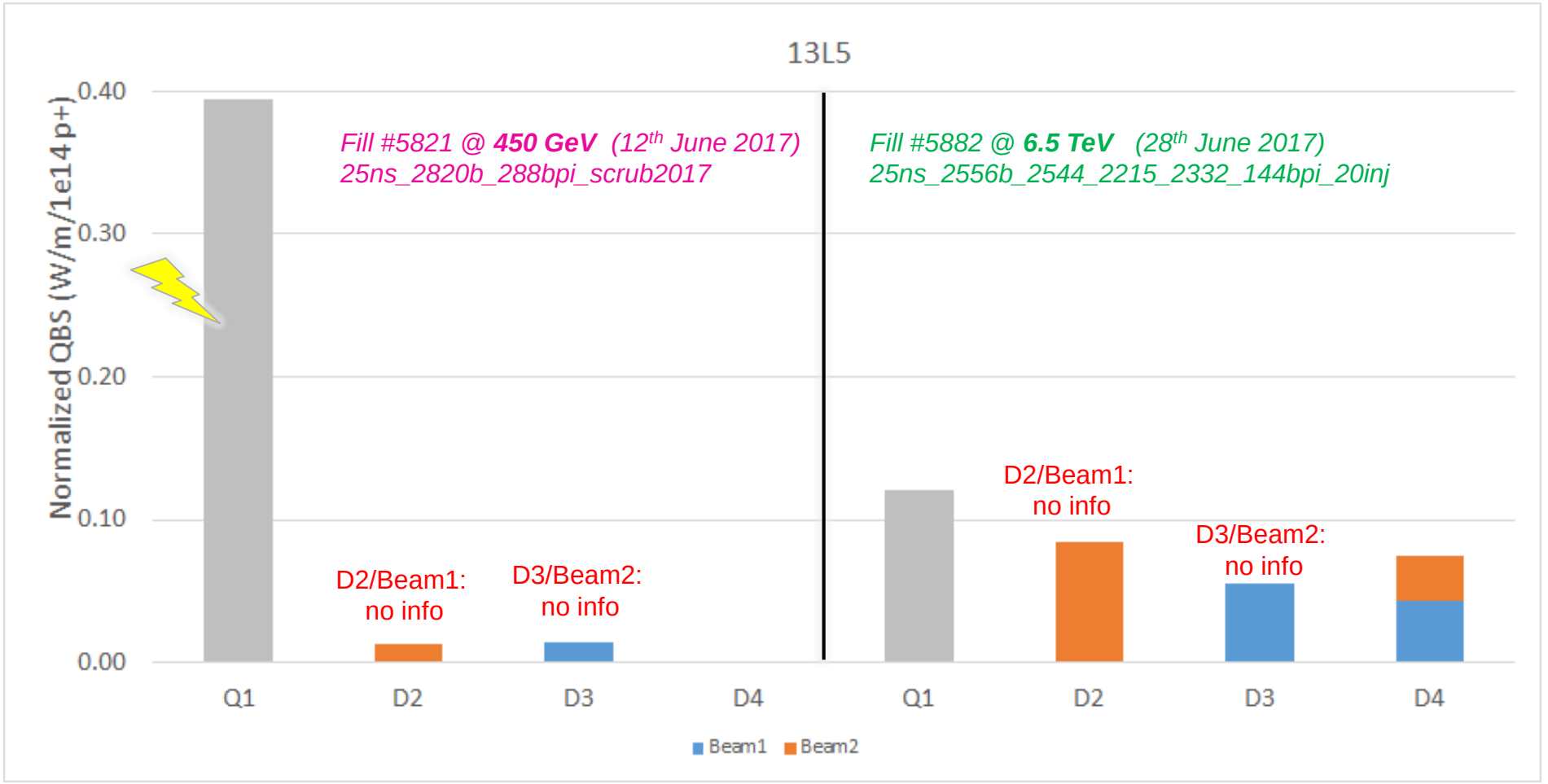
Normalized heat load in 34R4 @ 25 ns

3 anomalies
- Q1 beam 2 @ 450 GeV
- D3 beam 1 @ 450 GeV + 6.5 TeV



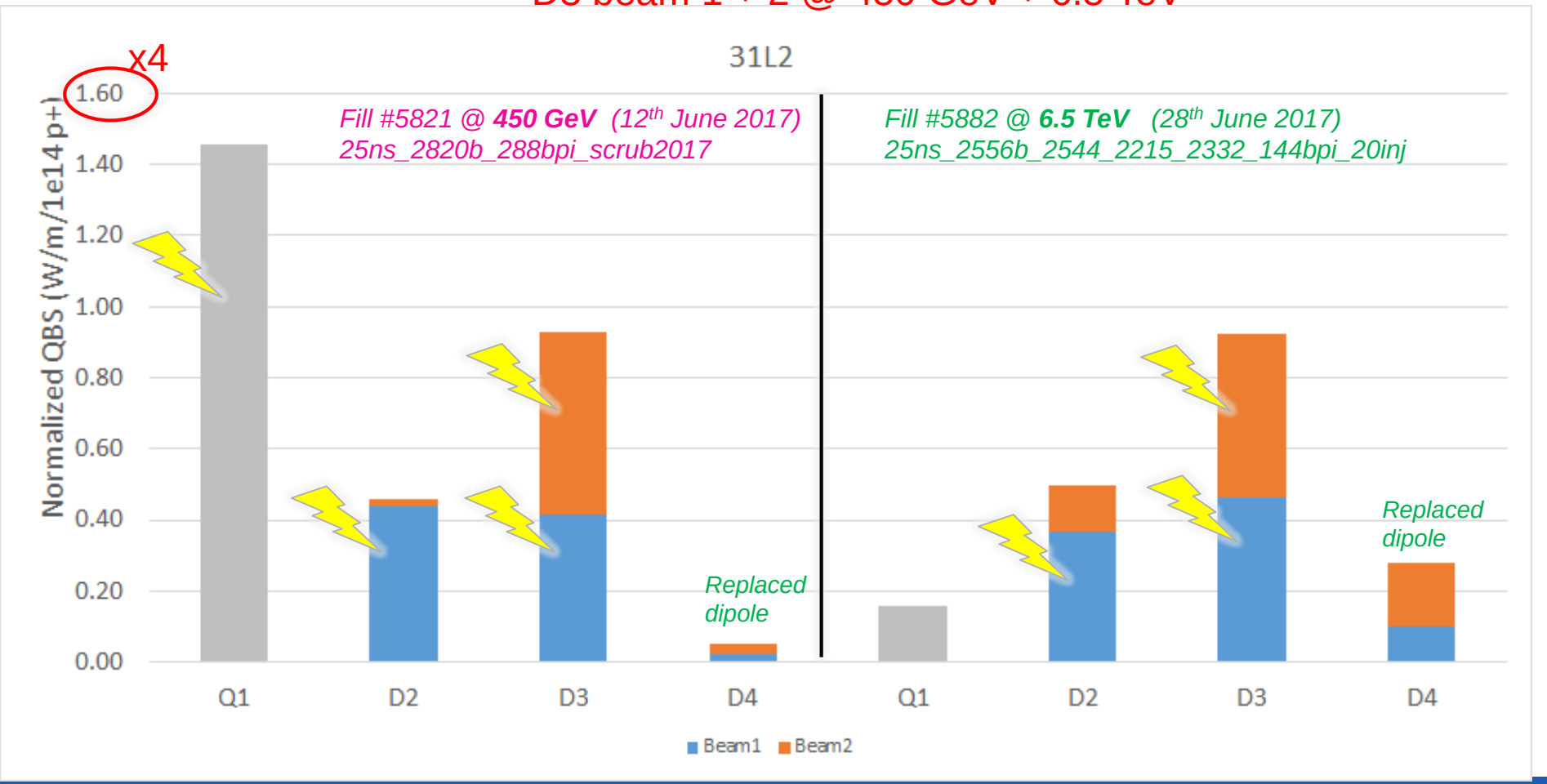
Normalized heat load in 13L5 @ 25 ns

1 anomaly:
- Q1 @ 450 GeV



Normalized heat load in 31L2 @ 25 ns

7 anomalies
- Q1 @ 450 GeV
- D2 beam 1 @ 450 GeV + 6.5 TeV
- D3 beam 1 + 2 @ 450 GeV + 6.5 TeV



Statistics in the 3 cells in S45

No e-cloud effect on quadrupoles at 6.5 TeV

Average QBS Normalized (W/m/1e14 p+)			
	450 GeV 25 ns (fill #5821)	6.5 TeV 25ns (fill #5882)	6.5 TeV 50ns (fill #5980)
Quadrupoles	0.17	0.06	0.05
Dipoles	0.02	0.07	0.03

Huge dispersion on dipoles at 25 ns !

Standard Deviation / Average (%)			
	450 GeV 25 ns (fill #5821)	6.5 TeV 25ns (fill #5882)	6.5 TeV 50ns (fill #5980)
Quadrupoles	67%	26%	8%
Dipoles	204%	101%	13%

Conclusion

- What have we observed ?
  - Sensors are good enough for BS heat load estimations per aperture
  - There is homogeneity across all magnets/apertures at 50 ns
  - Abnormal heat loads are observed in some magnets and apertures at 25 ns
  - The asymmetry beam1 / beam2 is NOT due to a cryogenic hydraulic problem in the cooling pipes (otherwise we should see a significant heat load on the whole cooling circuit length)
  - Replaced Dipole in S12 shows a much better behaviour than others
  - In S45 (low load sector)
    - ✓ we identified 1/24 (4%) abnormal aperture @ 6.5 TeV
  - In S12 (high load sector)
    - ✓ we identified 3/8 (37%) abnormal apertures @ 6.5 TeV